Measurement of Digital Transmission Systems
Operating under Section 15.247
March 23, 2005

Section 15.403(f) – Digital Modulation

Digital modulation is required for Digital Transmission Systems (DTS).

Digital modulation: The process by which the characteristics of a carrier wave are varied among a set of predetermined discrete values in accordance with a digital modulating function as specified in document ANSI C63.17-1998.

Section 15.31(m) – Number of Operating Frequencies

This rule specifies the number of operating frequencies to be examined for tunable equipment.

Section 15.207 – Power line conducted emissions

If the unit is AC powered, an AC power line conducted test is also required per this rule.

Section 15.247(a)(2) – Bandwidth.

Make the measurement with the spectrum analyzer's resolution bandwidth (RBW) = 100 kHz. In order to make an accurate measurement, set the span greater than RBW. The 6 dB bandwidth must be greater than 500 kHz.

Section 15.247(b) – Power output.

This is an RF conducted test. Use a direct connection between the antenna port of the transmitter and the spectrum analyzer, through suitable attenuation. Power Output Option 1 is a peak measurement. Power Output Option 2 is the same procedure used for UNII output power measurements. Either option can be used for DTS devices.

Power Output Option 1

Set the RBW greater than 6 dB bandwidth of the emission or use a peak power meter.

Power Output Option 2

Power output measurement allowed per Section 15.247(b)(3).

In the following, "T" is the transmission pulse duration over which the transmitter is on and transmitting at its maximum power control level. Measurements are performed with a spectrum analyzer. Three methods are provided to accommodate measurement limitations of the spectrum analyzer depending on signal parameters. Set resolution

bandwidth (RBW) = 1 MHz. Set span to encompass the entire emission bandwidth (EBW) of the signal. Use automatic setting for analyzer sweep time (except in Method #2). Check the sweep time to determine which procedure to use.

- If sweep time ≤ T, use Method #1 -- spectral trace averaging -- and sum the power across the band. Note that the hardware operation may be modified to extend the transmission time to achieve this condition for test purposes. (Method #1 may be used only if it results in averaging over intervals during which the transmitter is operating at its maximum power control level; intervals during which the transmitter is off or is transmitting at a reduced power level must not be included in the average.)

- If sweep time > T, then the choice of measurement procedure will depend on the EBW of the signal.

    - If EBW ≤ largest available RBW on the analyzer, use Method #2 -- zero-span mode with trace averaging -- and find the temporal peak. (Method #2 may be used only if it results in averaging over intervals during which the transmitter is operating at its maximum power control level; intervals during which the transmitter is off or is transmitting at a reduced power level must not be included in the average.)

    - If EBW > largest available RBW, use Method #3--video averaging with max hold and sum power across the band.

Method #1

1. Set span to encompass the entire emission bandwidth (EBW) of the signal.

2. Set RBW = 1 MHz.

3. Set VBW ≥ 3 MHz.

4. Use sample detector mode if bin width (i.e., span/number of points in spectrum display) < 0.5 RBW. Otherwise use peak detector mode.

5. Use a video trigger with the trigger level set to enable triggering only on full power pulses. Transmitter must operate at full control power for entire sweep of every sweep. If the device transmits continuously, with no off intervals or reduced power intervals, the trigger may be set to “free run”.

6. Trace average 100 traces in power averaging mode.

7. Compute power by integrating the spectrum across the 26 dB EBW of the signal. The integration can be performed using the spectrum analyzer’s band power measurement

function with band limits set equal to the EBW band edges or by summing power levels in each 1 MHz band in linear power terms. The 1 MHz band power levels to be summed can be obtained by averaging, in linear power terms, power levels in each frequency bin across the 1 MHz.

Method #2

1. Set zero span mode. Set center frequency to the midpoint between the -26 dB points of the signal.

2. Set RBW ≥ EBW.

3. Set VBW ≥ 3 RBW. [If VBW ≥ 3 RBW is not available, use highest available VBW, but VBW must be ≥ RBW]

4. Set sweep time = T

5. Use sample detector mode.

6. Use a video trigger with the trigger level set to enable triggering only on full power pulses.

7. Trace average 100 traces in power averaging mode.

8. Find the peak of the resulting average trace.

Method #3

1. Set span to encompass the entire emission bandwidth (EBW) of the signal.

2. Set sweep trigger to "free run".

3. Set RBW = 1 MHz. Set VBW ≥ 1/T

4. Use linear display mode.

5. Use sample detector mode if bin width (i.e., span/number of points in spectrum) < 0.5 RBW. Otherwise use peak detector mode.

6. Set max hold.

7. Allow max hold to run for 60 seconds.

8. Compute power by integrating the spectrum across the 26 dB EBW or apply a bandwidth correction factor of 10 log (EBW/1 MHz) to the spectral peak of the emission. The integration can be performed using the spectrum analyzer's band

power measurement function with band limits set equal to the EBW band edges or by summing power levels in each 1 MHz band in linear power terms. The 1 MHz band power levels to be summed can be obtained by averaging, in linear power terms, power levels in each frequency bin across the 1 MHz.

Section 15.247(b)(5) – RF safety

Ensure that measurements/calculations in the exhibits showing RF safety compliance are consistent throughout the filing.

Section 15.247(c) – Spurious emissions.

The following tests are required:

1. **RF antenna conducted test:** Set RBW = 100 kHz, Video bandwidth (VBW) > RBW, scan up through 10th harmonic. All harmonics/spurs must be at least 20 dB down from the highest emission level within the authorized band *as measured with a 100 kHz RBW. Note: If the device complies with the use of power option 2 the attenuation under this paragraph shall be 30 dB instead of 20 dB.*

2. **Radiated emission test:** Applies to harmonics/spurs that fall in the restricted bands listed in Section 15.205. The maximum permitted average field strength is listed in Section 15.209. A pre-amp (and possibly a high-pass filter) is necessary for this measurement. For measurements above 1 GHz, set RBW = 1MHz, VBW = 10 Hz, Sweep: Auto. If the emission is pulsed, modify the unit for continuous operation; use the settings shown above, then correct the reading by subtracting the peak-average correction factor, derived from the appropriate duty cycle calculation. See Section 15.35(b) and (c).

Section 15.247(d) – Power spectral density (PSD).

The same method of determining the conducted output power shall be used to determine the power spectral density. If a peak output power is measured, then a peak power spectral density measurement is required. If an average output power is measured, then an average power spectral density measurement should be used. Use PSD Option 1 if Power output Option 1 was used. Use PSD Option 2 if power output Option 2 was used.

PSD Option 1

Locate and zoom in on emission peak(s) within the passband. Set RBW = 3 kHz, VBW > RBW, sweep= (SPAN/3 kHz) e.g., for a span of 1.5 MHz, the sweep should be $1.5 \times 10^6 \div 3 \times 10^3 = 500$ seconds. The peak level measured must be no greater than + 8 dBm. If external attenuation is used, don't forget to add this value to the reading. Use the following guidelines for modifying the power spectral density measurement procedure when necessary.

- For devices with spectrum line spacing greater than 3 kHz no change is required.

- For devices with spectrum line spacing equal to or less than 3 kHz, the resolution bandwidth must be reduced below 3 kHz until the individual lines in the spectrum are resolved. The measurement data must then be normalized to 3 kHz by summing the power of all the individual spectral lines within a 3kHz band (in linear power units) to determine compliance.

- If the spectrum line spacing cannot be resolved on the available spectrum analyzer, the noise density function on most modern conventional spectrum analyzers will directly measure the noise power density normalized to a 1 Hz noise power bandwidth. Add 35 dB for correction to 3 kHz.

- Should all the above fail or any controversy develop regarding accuracy of measurement, the FCC Laboratory will use the HP 89440A Vector Signal Analyzer for final measurement unless a clear showing can be made for a further alternate.

PSD Option 2

Locate and zoom in on emission peak(s) within the passband.

- Set RBW = 3 kHz.

- Set VBW $\geq$ 9 kHz.

- Set Sweep time to Automatic

- Use a peak detector. A sample detector mode can be used only if the following can be achieved with automatic sweep time and adjusting the bin width.

    1. Bin width (i.e., span/number of points in spectrum display) < 0.5 RBW.

    2. The transmission pulse or sequence of pulses remains at maximum transmit power throughout each of the 100 sweeps of averaging and that the interval between pulses is not included in any of the sweeps (e.g., 100 sweeps should occur during one transmission, or each sweep gated to occur during a transmission).

        Note: If condition 2 cannot be achieved, then PSD Option 1 (peak detector on max hold) must be used and trace averaging cannot be used.

- Use a video trigger with the trigger level set to enable triggering only on full power pulses. Transmitter must operate at full control power for entire sweep of every sweep. If the device transmits continuously, with no off intervals or reduced power intervals, the trigger may be set to “free run”.

- Trace average 100 traces in power averaging mode. Do not use video averaging mode.

  Note: Some analyzers will automatically select sample mode when trace averaging is selected. If a peak detector is used, then peak detector must be manually selected when trace averaging is enabled.

ALTERNATIVE TEST PROCEDURES

If antenna conducted tests cannot be performed on this device, radiated tests to show compliance with the various conducted requirements of Section 15.247 are acceptable. As stated previously, a pre-amp must be used in making the following measurements.

1. Calculate the transmitter's peak power using the following equation:

   Where: E = the measured maximum field strength in V/m.

   Set the RBW > 6dB bandwidth of the emission or use a peak power meter.

   P = (E x d) squared / (30 x G)

   G = the numeric gain of the transmitting antenna over an isotropic radiator.

   d = the distance in meters from which the field strength was measured.

   P = the power in watts for which you are solving:

2. Measure the power spectral density as follows:

   A. Tune the analyzer to the highest point of the maximized fundamental emission. Reset the analyzer to a RBW = 3 kHz, VBW > RBW, span = 300 kHz, sweep = 100 sec.

   B. From the peak level obtained in (A), derive the field strength, E, by applying the appropriate antenna factor, cable loss, pre-amp gain, etc. Using the equation listed in (1), calculate a power level for comparison to the + 8 dBm limit.

      Note: The above settings are used for peak measurements. The optional procedures for output power and power spectral density measurements can be used when applicable.